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"Laser Technology"

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LASER TECHNOLOGY: APPLICATIONS FOR NONWOVENS AND COMPOSITES

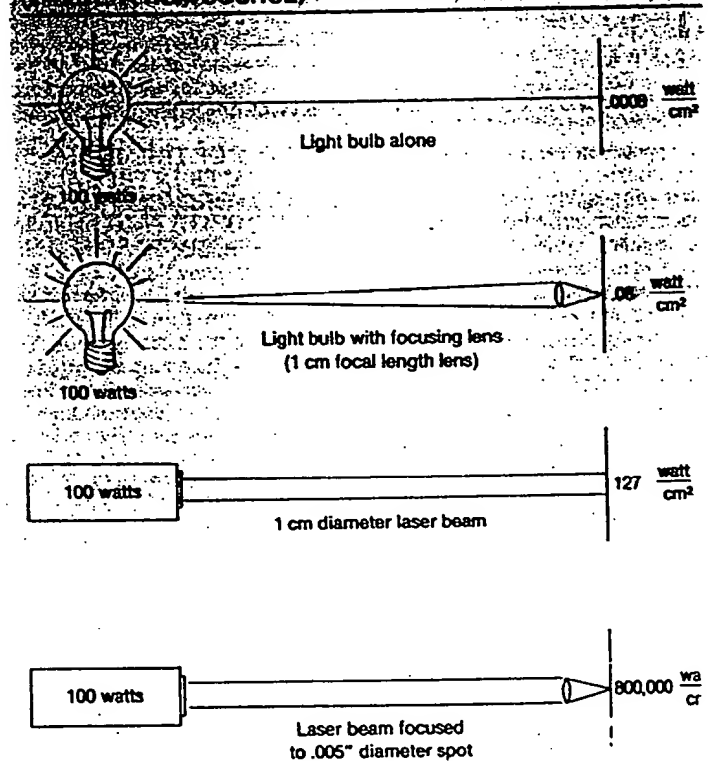
Lasers are a relatively new technology, having been invented in the late 1950's. In the intervening years, they have been rapidly accepted by industry because they can cut, weld, drill, scribe, heat treat and engrave very precisely, very quickly and in ways that were not possible before their invention. The resulting products often cost less and/or perform better.

Lasers can be considered an idea light bulb since the light is emittec as a single color and is almost parallel The light is easy to focus with simpl lenses to defraction limited spot size and doesn't require complicated filter to provide the particular color of ligh required for the job.

Figure 1 provides a simple illustra tion of how a laser differs from :

FIGURE 1

[illegible] LIGHT BULB VS. LASER [illegible] SOURCE)



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conventional light source that radiates in all directions. The 100 watt laser radiates the same total amount of energy as a 100 watt light bulb, but the maximum energy density available from the laser is 10 million times greater in a focused spot than that available from a light bulb.

Industrial lasers emit the energy required to provide heat for processing a material. They allow a very large amount of energy to be focused on a small, well-defined spot, the energy of which can be many orders of magnitude greater than that obtained by any other process. The laser heats, melts or vaporizes materials in this very small, well-defined area, applying the heat only where it is needed and giving a very small heat-affected zone outside of the spot where the energy is focused.

ADVANTAGES

Some of the basic advantages of lasers are:

The laser is a single point cutting source with a very small point, .001 inches to .020 inches in diameter, allowing for very small cut widths or small welds. This point can be moved in any direction, unlike other processes like knives or saws.

It is a forceless process allowing very flimsy parts to be cut with no support.

The beam is always sharp; thus it can cut very hard or abrasive materials.

The laser works well with Computer Numerical Controls because the energy in the focused spot can be easily controlled and made to cut in any direction.

It cuts sticky materials that would otherwise gum up a blade.

The laser provides a very small heat-affected zone compared to other processes.

It can cut at a very high speed as the speed at which a material can be processed is limited only by the power available from the laser.

This article discusses how the beam interacts with a material rather than how the beam is generated. We will just assume that there is a black box generating a beam of continuous or pulsed electromagnetic energy of essentially the same wavelength and collimated, depending on laser type, such that the beam has between a 1 and 20 milliradian divergence.

BASIC LASER JARGON

CO_2 Laser: has flowing gas mixture of helium, nitrogen and carbon dioxide as lasing medium; emits 10.6 micron wavelength

Collimator: device used to reduce a beam divergence

cw: continuous wave

Divergence: the angle at which the beam spreads in the far field

Flowing Gas: type of laser design in which lasing medium is a flowing gas mixture; examples are CO_2 and Argon lasers

Hz (Hertz): a unit of frequency equal to one cycle per second; used to describe the pulses of solid state lasers

j (joule): watt second of energy — measurement frequently given for laser output in pulsed operation

Laser: acronym for Light Amplification by Stimulated Emission of Radiation

Mode: distribution of energy in the beam; the best mode for cutting, a Gaussian curve mode, has all the energy in an outside ring and none in the center

Nd:glass: solid state laser with glass rod as lasing medium; pumped (excited) with flash lamp

1.06 micron: wavelength emitted by Nd:YAG and Nd:glass lasers; absorbed well by metals but many glasses and plastics are transparent; not visible to the eye but is focused by the eye

pps: pulse per second

Pulsing: done electronically in flowing gas lasers and with flash lamps in solid state lasers

Solid State: lasing medium is solid rod, usually a crystalline structure

10.6 micron: wavelength emitted by CO_2 lasers; absorbed well by glass, plastics, organic substances and rock; the same wavelength as heat and is not visible to or focused by the eye

INDUSTRIAL LASER TYPES

The different lasers mentioned in the following paragraphs are examples of industrial lasers that are used in a normal production environment. They focus a large amount of energy on a very small, well-defined spot, 0.5 to 0.1 mm or less in diameter, and cut or drill by vaporizing the material.

There are two basic classes of industrial lasers at this time, *solid state* and *flowing gas*. The first, the Nd:YAG, is the solid state laser and is typically pulsed. The electromagnetic radiation it emits is in the near infrared at 1.06 microns, a wavelength absorbed well by metals, but glass and many plastics are transparent.

Because of their being pumped by flash lamps, Nd:YAG are capable of very high peak powers. They can pulse at up to 100 Hz, with pulses of 2 to 3 joules, or down to 1 Hz, with 60- to 70-joule pulses 1 ms long. Peak powers can be quite substantial; for example, an Apollo Model 1825, manufactured by Apollo Lasers Inc., operating at 6.5 joules/pulse with a pulse of 0.4 ms long and 40 Hz, provides a peak power of 10,000 w or an average power of 200 w. The largest commercially available pulsed Nd:YAG can put out up to 400 w average power.

Pulsed Nd:YAG lasers are available in several configurations. The Apollo 1825 has a capacitor discharge power supply for its single rod; when pulsed at peak power this design produces a large divergence or beam spread. In order to minimize the spot diameter for drilling or cutting applications, these lasers usually are operated at lower average powers.

The 400 w JK 830LD, manufactured by JK Lasers, is an example of a second configuration Nd:YAG. When the low divergence option is installed, it reduces the power to approximately 150 w, allowing much lower divergence and thus a smaller, brighter spot. A third design, which was not available for these tests, uses 2 Nd:YAG rods and typically has the lowest divergence and the highest power pulses. This design probably is the best cutter or driller for composites.

The other solid state laser used industrially is the pulsed Nd:glass laser which operates at less than 1 pulse per second and is primarily used for drilling.

The CO_2 laser represents the other major class of lasers, the flowing gas laser. It is approximately 10% efficient and can be either pulsed, with lasers available having peak pulsed powers of 5 kw or greater, or used cw with powers of 1 kw or greater. CO_2 lasers emit energy at 10.6 microns which is in the far infrared. This wavelength is absorbed well by nonmetals. Metals, however, reflect at least 90% of 10.6 micron energy at room temperature, though the absorption increases with temperature. This makes it difficult to process metals except with high power lasers having very high energy density.

CO_2 lasers come in many configurations: slow flow, fast axial flow, transverse flow and TEA (transverse exited atmospheric). The two basic designs that are good for cutting at this time are slow and fast axial flow, both of which offer low divergence and good mode (mode is the distribution of energy in the beam). The slow flow lasers, exemplified by Coherent General's S48, M48-2, M46 and M42, are mature technology lasers that have been used industrially since the mid 1970's. They are normally continuous wave lasers but can be electronically pulsed up to 2000 Hz by turning the power supply on and off. Some of them also have an "Enhanced Pulse" power supply design that allows up to 5 times or more the continuous wave power for 100 microseconds or more.

Slow flow CO_2 lasers have the disadvantage of becoming very large in order to achieve high powers. Fast flow lasers overcome this disadvantage by using blowers to move the gas through the discharge region and by cooling the gas with external heat exchangers rather than by conduction through the tube walls. This allows much greater powers (up to 600 w/m of length), and thus they are the primary industrial design used for 1-10 kw lasers at this point. They can be electronically pulsed but don't provide the intense pulses that the large, slow flow lasers do.

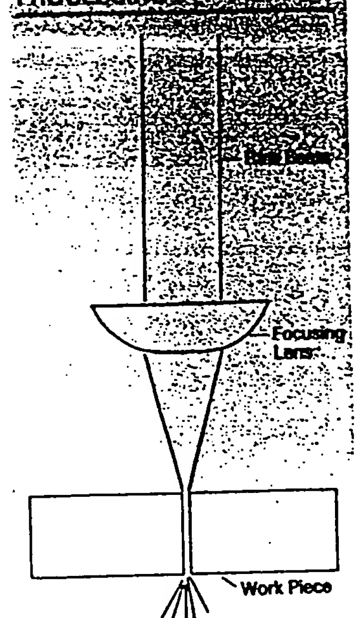
MATERIALS VS. LASER SELECTION

When deciding on using a laser for material processing, there are three primary considerations. For a more detailed analysis refer to The Guide for Material Processing by Lasers published by the Laser Institute of America. The three primary considerations are:

1) Absorption of the energy: How much of the energy is absorbed by the material and how does this vary with the temperature of the material? Some materials may be reflective or transparent.

FIGURE 2

LASER MATERIAL PROCESSING



2) Thermal diffusivity: How fast does whatever heat is absorbed in the material conduct away? This is a function of thermal conductivity, the specific heat and thickness of the material.

3) Reaction temperature: How hot do you have to get the material to cause it to melt, vaporize, etc., and how much heat is required to reach that temperature?

SECONDARY CONSIDERATIONS

Secondary considerations for laser processing include:

1) Heat-affected zone: Since lasers are a thermal cutting process, there will be some zone, maybe as small as .001 inch, where the material is heated. Depending on the material there may be charring, hardening, flame polishing, etc.

2) Smoke or debris: As lasers cut they vaporize or decompose the material, and one must consider how to eliminate or minimize the amount of vaporized or decomposed material that coats out on the part.

3) Burr on the edge or dross: Some materials may exhibit a burr of melted material or slag being left on the edge after cutting.

4) Thermal expansion of the part: This is important in brittle materials, such as some ceramics or glasses, where the heat introduced into the part causes thermal expansion and cracking.

5) Tolerances: Since there is no well defined edge to the beam, one should consider carefully the squareness specifications, profile, thickness, etc. Laser cutting can be thought of as basically a ±.001 inch tolerance process. Tolerances much smaller that that can be held, but much care has to be paid to material properties, laser and beam parameters and equipment design.

6) Reaction products and personal safety: The reaction products from vaporizing the material need to be determined and their effects on human health analyzed.

7) Safety: Eye safety is the primary concern, but one cannot forget that a high energy beam can cut or burn people. Factors to consider are the energy level, wave length and the level of training personnel have had. Historically the most dangerous aspect of the laser is the high voltage present in most laser power supplies.

8) Assist gases: What gas may be used to help oxidize the material or to protect against oxidation?

9) Dissimilar materials: These require special consideration because they are a combination of materials, usually with different thermal characteristics. This applies to composites, of course, and welding different metals together.

There are several applications in which lasers are especially suited for use in processing flat sheets such as nonwovens and plastic films. These include slitting and crosscutting webs, profile cutting and perforating.

SLITTING AND CROSSCUTTING OF WEBS

Bonding of Cut Edge: Because thermoplastic materials that are being slit will have some bonding of the edge, this edge won't fray or have strings come loose. This can be very useful if the web is subsequently coated or if the application requires no loose fibers.

Strengthening of Cut Edge: Some materials, such as polyester films, tear easily when cut with a knife. The sealed edge provided by the laser cut allows much greater stresses.

No Contamination: Medical applications where no contamination by metal particles can be tolerated are a good example. The only thing to watch out for is the smoke and vaporized material generated by the laser cut.

Abrasive Materials: Very difficult and abrasive materials, such as paper with clay in it, can be cut on a production basis without ever having to change blades.

Non-straight Lines: Since the laser beam can cut in any direction and is very easily bounced around with mirrors, the edges of slit sheets can be cut in very unusual shapes. These shapes can be easily changed since the beam motion is usually controlled by a computer and the profile can be changed by using a new program.

Perforated Lines: The laser can be pulsed on and off very rapidly so materials can be perforated at very fast speeds and the perforation pattern can be changed at will. An example of this is paper for computers which is laser perforated with a hole pattern so fine that it is almost impossible to tell if it was sheared or torn apart.

Scoring Part Way Through Cutting: Materials can be scribed or scored at a set depth without the thickness of the material being a problem. Sheets can be scribed so they can be folded on the line accurately. Material can be cut through to the backing so that the release paper can be used to transport the part and the part won't fall out.

Sticky Materials: Adhesives can be cut without buildup on the blades, and coated materials can be cut before the coating is dry.

Cut On and Off Edges: Materials can be slit with a laser beam going on and off the edge at very low angles without any problems.

High Strength, Difficult to Cut Materials: Materials such as Kevlar that are difficult to cut by other processes are easy to cut with the laser. Kevlar, for example, cuts like a thermoset plastic with the laser.

High Speed: The speed at which a material can be processed is limited only by the amount of energy available from the laser.

PROFILE CUTTING

Cuts Any Direction: Since it is a single point cutting technique, the laser can cut very complex shapes such as small holes, notches and points easily under computer control. The direction also can be changed without any change in the cutter orientation.

No Force: Since the laser exerts no force during the cutting process, it can cut very delicate materials without any support.

High Speed: The laser is limited as to how fast it can cut only by the amount of laser power available and how fast the beam can be manipulated. Cloth is being cut into suits and other products at very high speeds.

Minimum Waste: Since the laser beam is very small, cuts any direction and is forceless, pieces can be nested next to each other with no allowance for material between pieces.

PERFORATING

Very Small Holes: Since the focused spot can be 0.1 mm in diameter, very small holes can be drilled in production.

Fast Drilling Speeds: Holes can be drilled as fast as the beam can be pulsed and moved from hole to hole. In some cases this can be as fast as 10,000 holes per second.

No Tool Breakage: Since the tool is a beam of light, the tool never needs to be replaced, eliminating down time because of punch breakage.

Fast Pattern Changes: The laser, because it is electronically controlled, can change from one pattern to another instantly and eliminate down time due to tool changes.

SAFETY OF INDUSTRIAL LASERS

Lasers, like any other tool that can cut, need to be treated with respect, but CO_2 lasers (the primary lasers used for nonmetal processing) emit infrared heat so they are very safe. Standard safety glasses are opaque to this wavelength light, and the eye won't focus this wavelength. The primary safety considerations are the high voltages used in most laser power supplies and the vapors which may be emitted from the cutting or drilling process.

SUMMARY

Lasers have proven to be the most economic solution to many processing problems. They are reliable and proven in industrial material processing situations. They are inexpensive to operate and work well in high volume production. But like any other process, they can't do everything and need to be carefully considered relative to other processes that also may do the job. Lasers, since they are a heat process, require that the manufacturing engineer pay close attention to the chemical make-up of the materials involved. Slight changes from a mechanical or chemical point of view can make marked changes in cut quality and speed. N/W